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(54) **PROTECTIVE LAYER(S) IN ORGANIC IMAGE SENSORS**

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H01L 51/44 (2006.01)
H01L 27/30 (2006.01)
H01L 51/00 (2006.01)

(52) **U.S. Cl.**
CPC ***H01L 51/448*** (2013.01); ***H01L 27/307*** (2013.01); ***H01L 51/0017*** (2013.01); ***H01L 51/442*** (2013.01); ***H01L 51/447*** (2013.01); *H01L 2251/306* (2013.01); *H01L 2251/308* (2013.01)

(58) **Field of Classification Search**
CPC H01L 51/447; H01L 27/322; H01L 27/307
USPC 257/40; 136/263; 250/200
See application file for complete search history.

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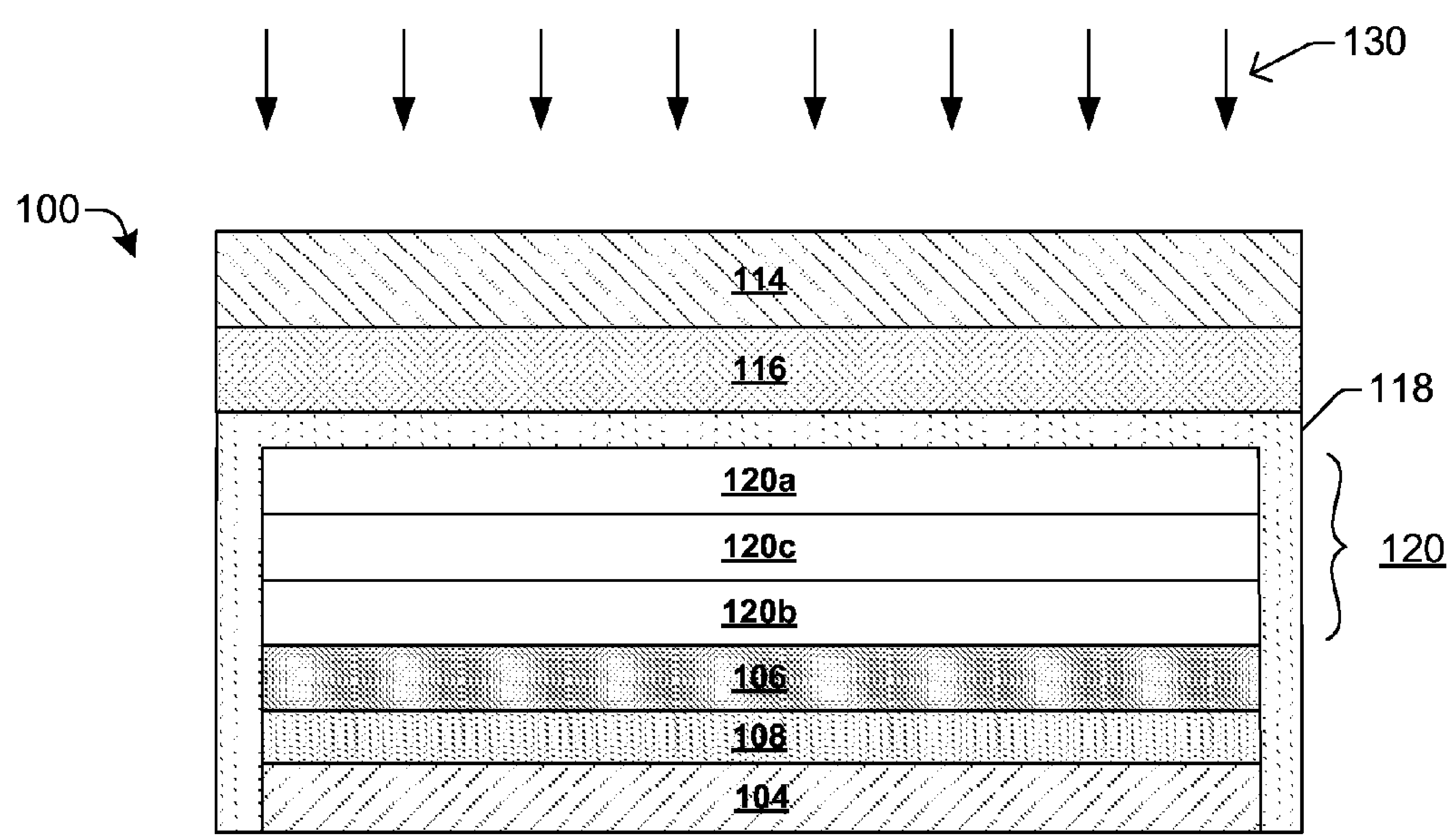
(57) **ABSTRACT**

The present disclosure relates to an organic image sensor and an associated method. By inserting an inorganic protective layer between an electrode and an organic photo active region of the image sensor, the organic photo active region is protected from moisture, oxygen or following process damage. The inorganic protective layers also help to suppress the leakage in the dark. In some embodiments, the organic image sensor comprises a first electrode, an organic photoelectrical conversion structure disposed over the first electrode and a second electrode disposed over the organic photoelectrical conversion structure. The organic image sensor further comprises a first protective structure covering a top surface and a sidewall of the organic photoelectrical conversion structure.

20 Claims, 6 Drawing Sheets



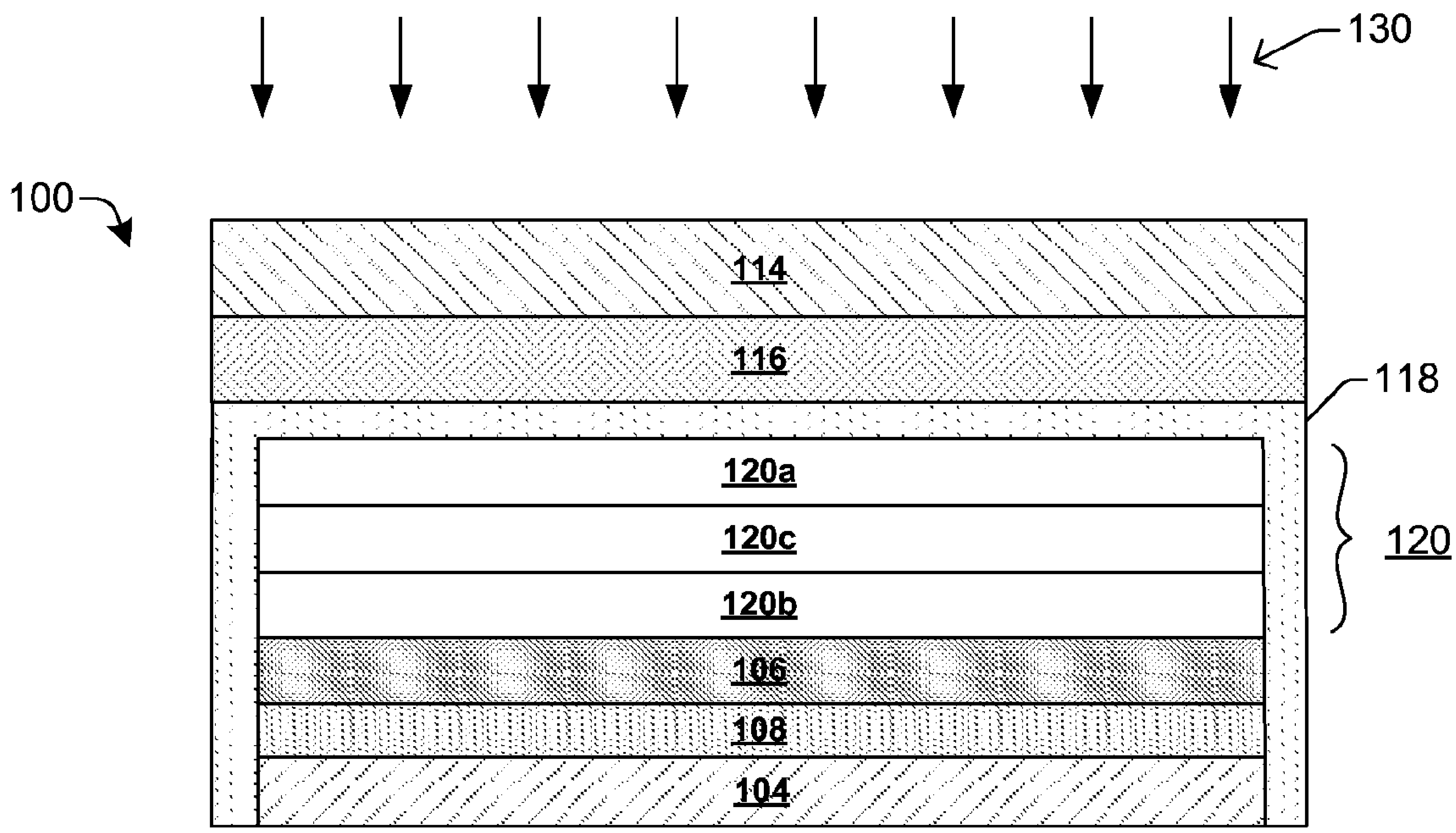

130
100
114
116
118
120a
120c
120b
120
106
108
104

FIG. 1A

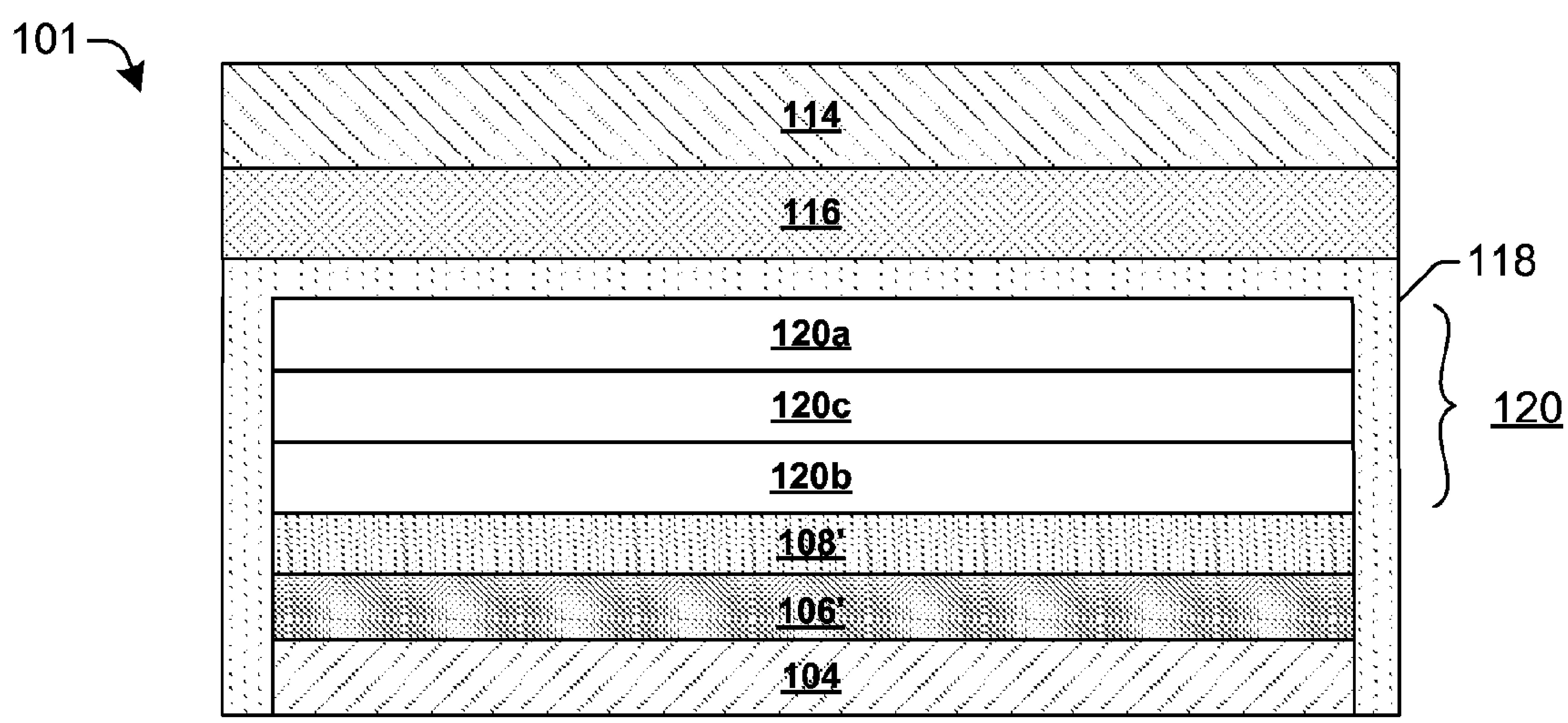

101
114
116
118
120a
120c
120b
120
108'
106'
104

FIG. 1B

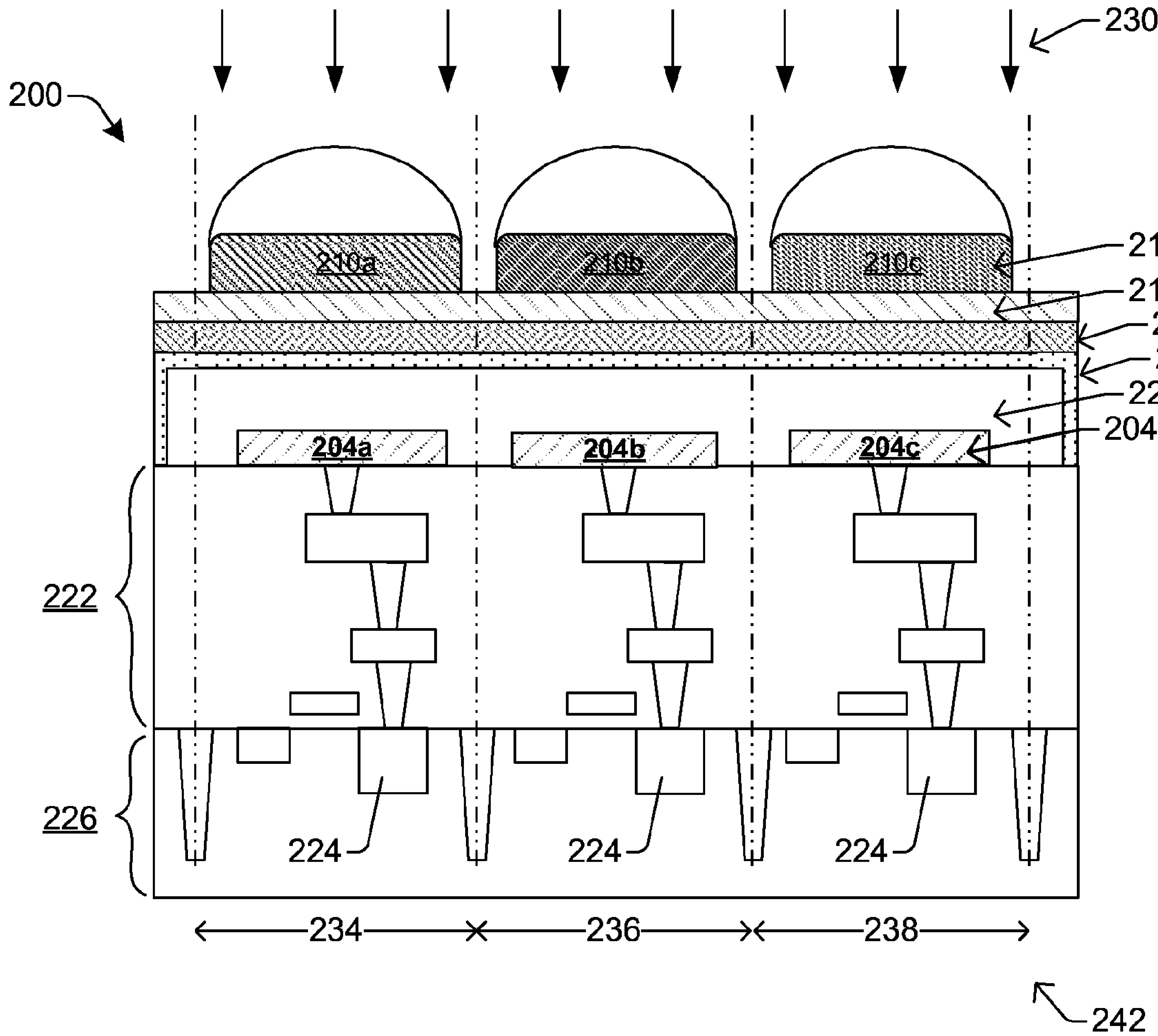

230
200
210a
210b
210c
210
214
216
218
220
204a
204b
204c
204
222
226
224
224
224
234
236
238
242

FIG. 2

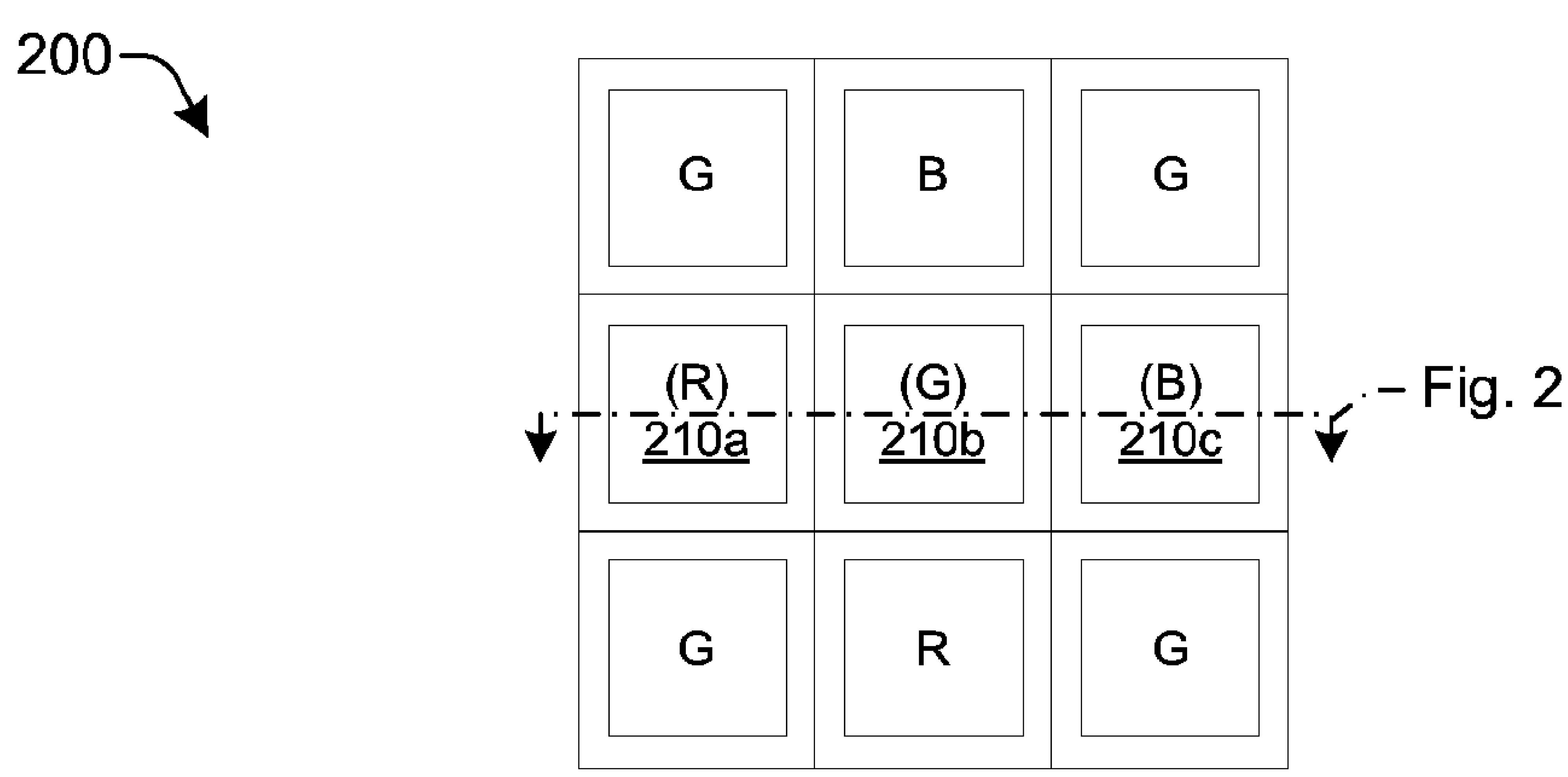

200
G
B
G
(R)
210a
(G)
210b
(B)
210c
Fig. 2
G
R
G

FIG. 3

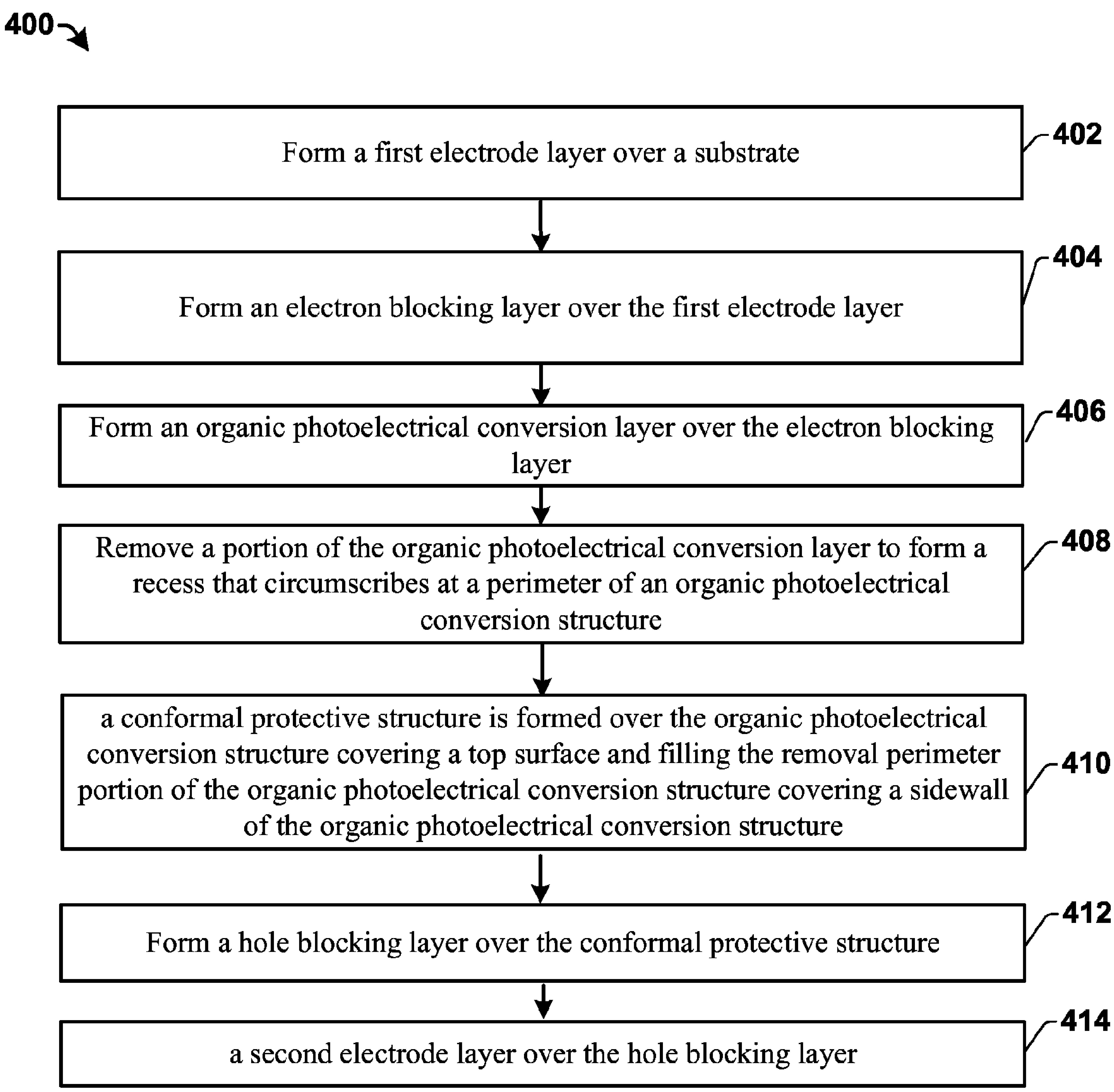

400
Form a first electrode layer over a substrate
402
Form an electron blocking layer over the first electrode layer
404
Form an organic photoelectrical conversion layer over the electron blocking layer
406
Remove a portion of the organic photoelectrical conversion layer to form a recess that circumscribes at a perimeter of an organic photoelectrical conversion structure
408
a conformal protective structure is formed over the organic photoelectrical conversion structure covering a top surface and filling the removal perimeter portion of the organic photoelectrical conversion structure covering a sidewall of the organic photoelectrical conversion structure
410
Form a hole blocking layer over the conformal protective structure
412
a second electrode layer over the hole blocking layer
414

Fig. 4

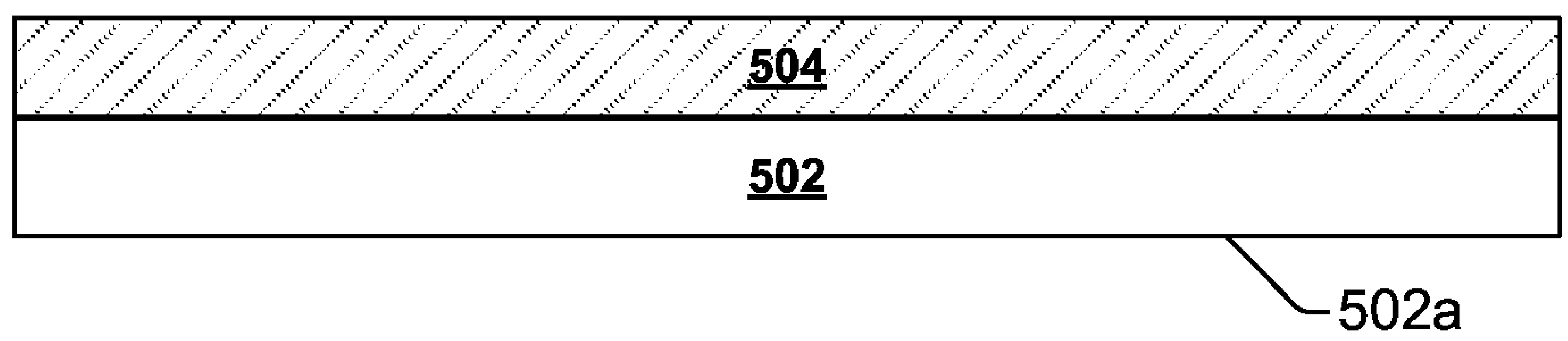


FIG. 5A

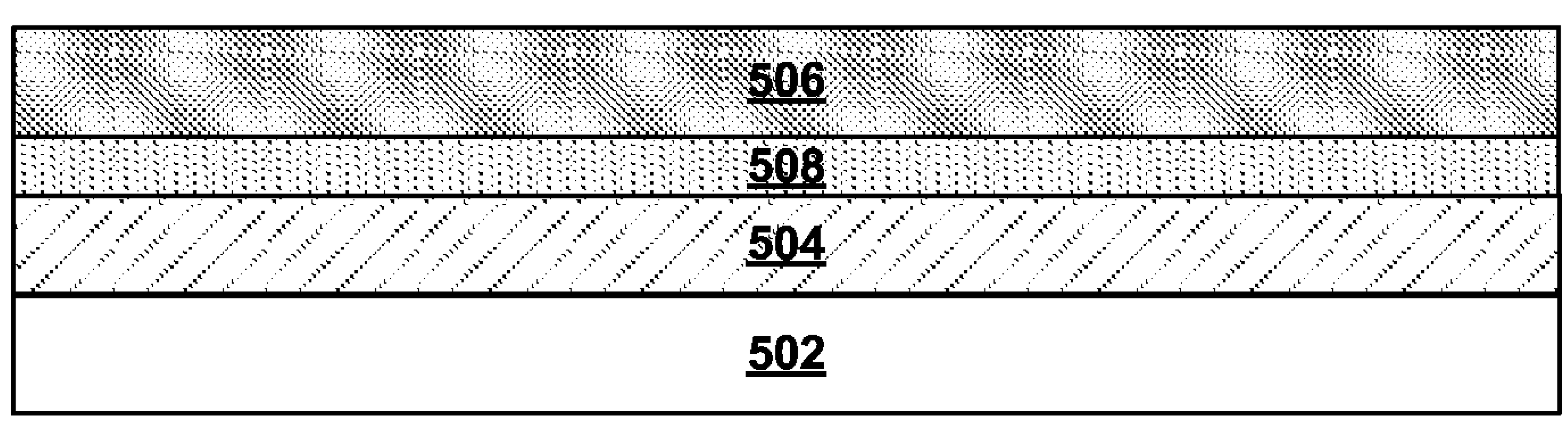


FIG. 5B

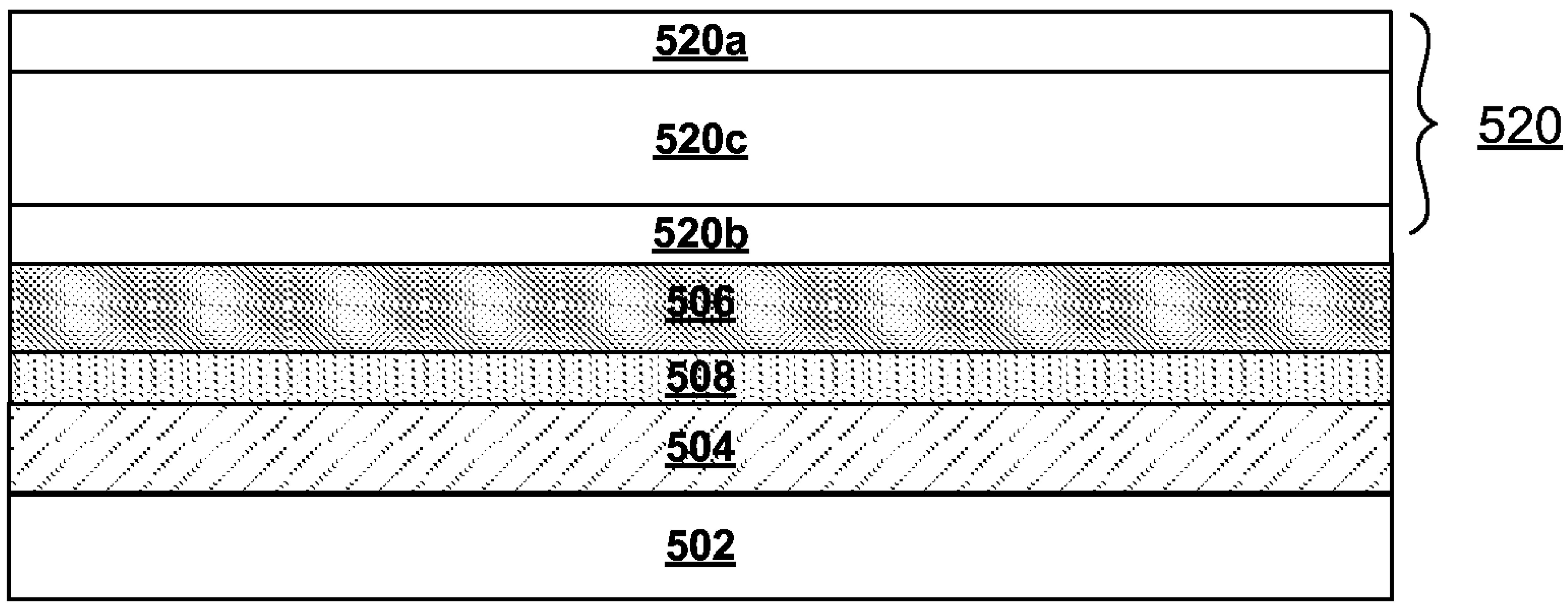

520a
520c
520b
520
506
508
504
502

FIG. 5C

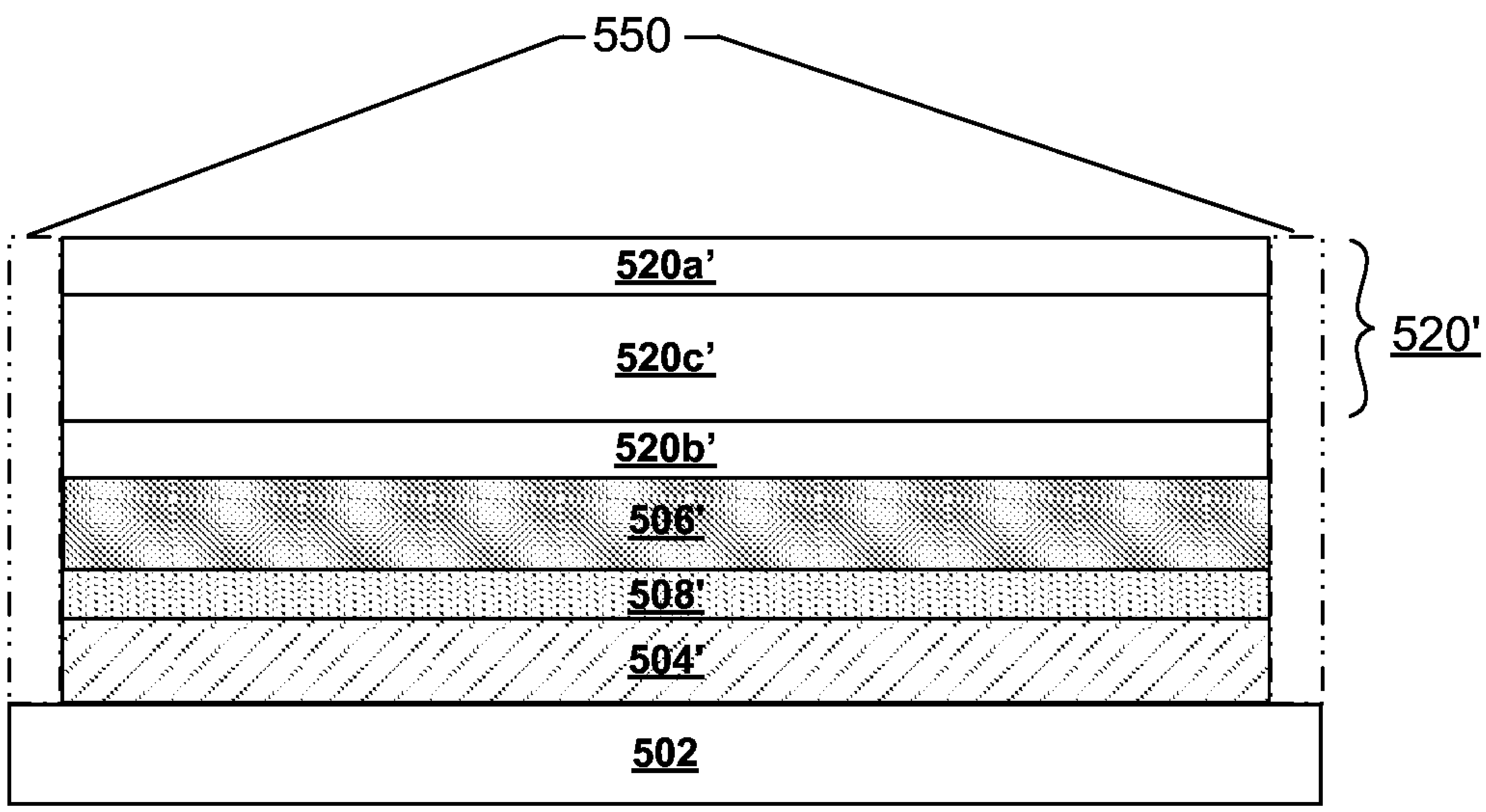

550
520a'
520c'
520b'
520'
506'
508'
504'
502

FIG. 5D

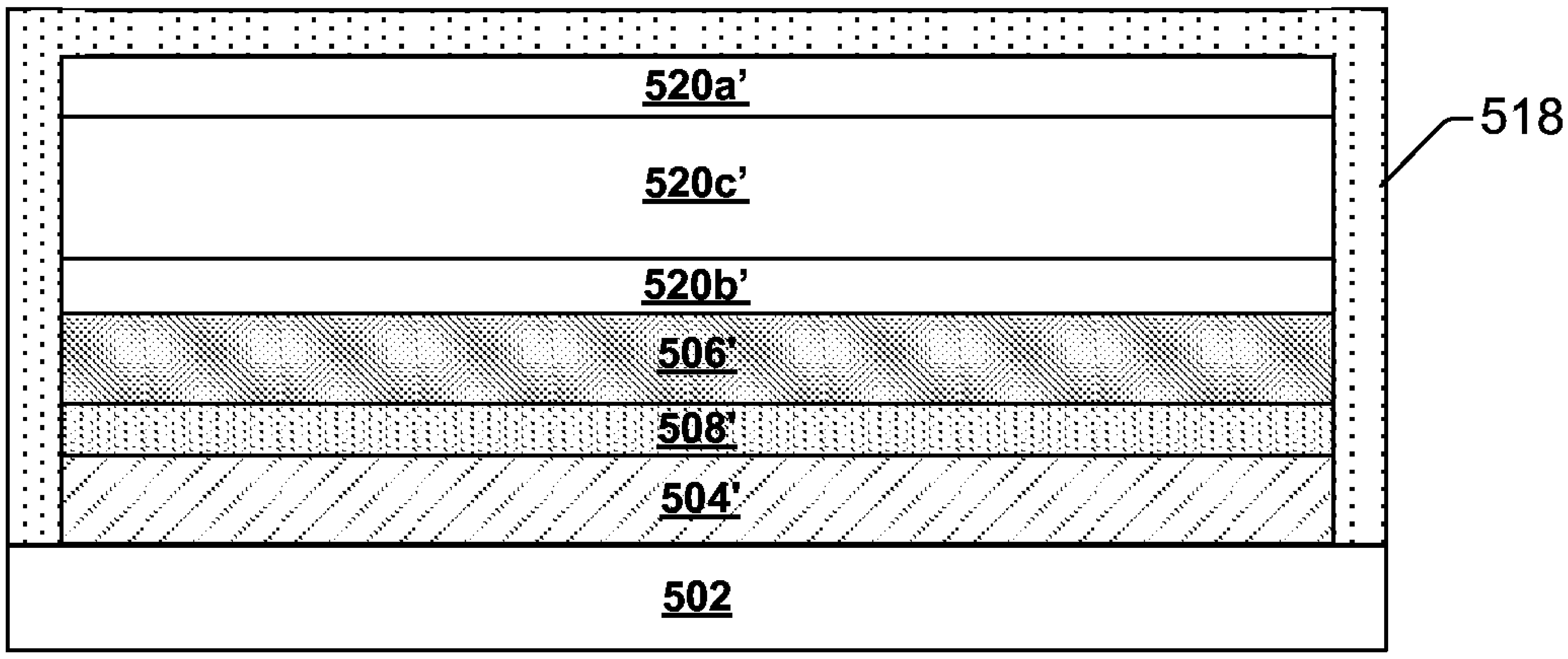

520a'
520c'
520b'
506'
508'
504'
502
518

FIG. 5E

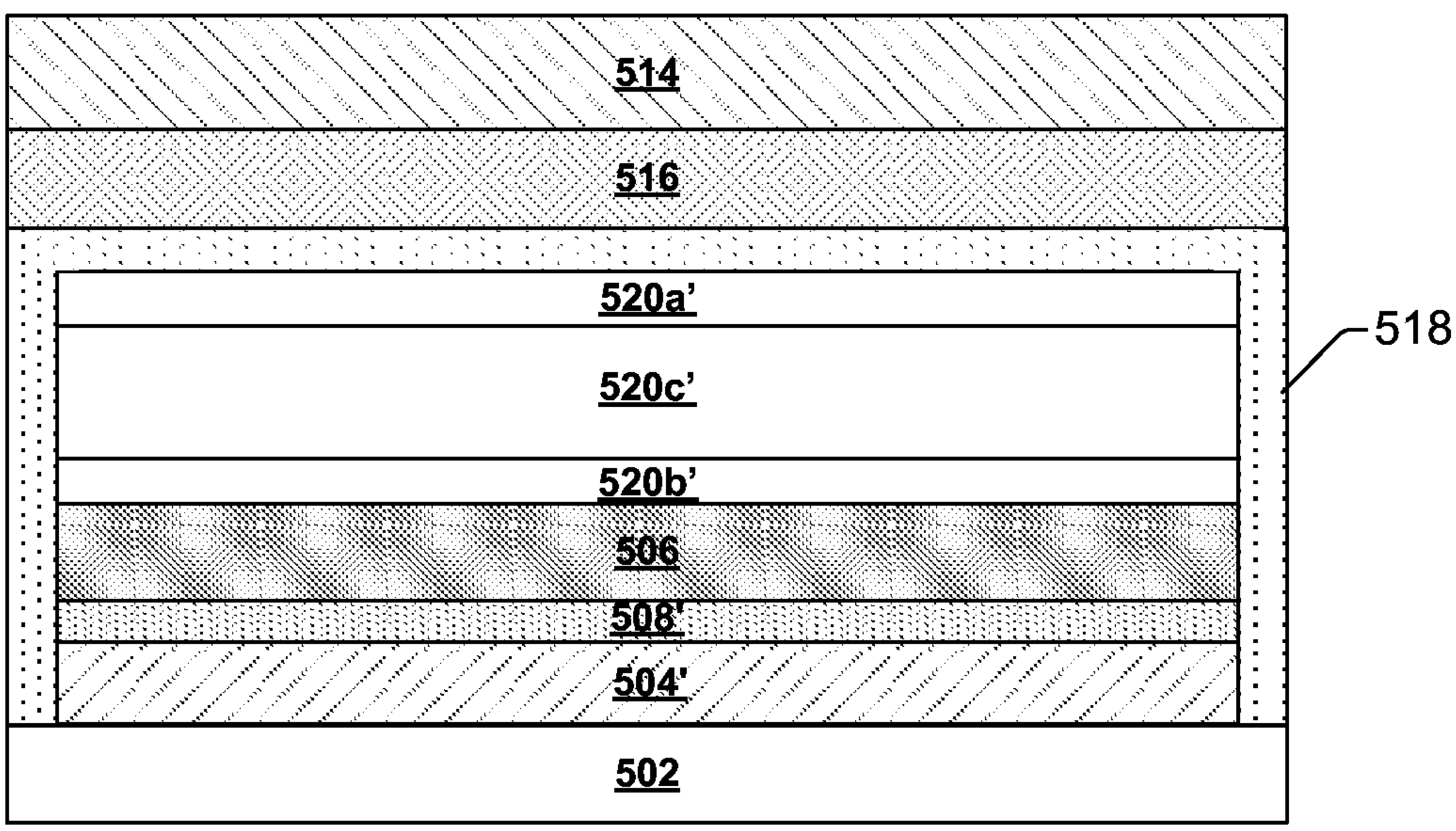

514
516
520a'
520c'
520b'
506
508'
504'
502
518

FIG. 5F

PROTECTIVE LAYER(S) IN ORGANIC IMAGE SENSORS

BACKGROUND

Digital cameras and other digital imaging devices use arrays of millions of tiny photodetectors or pixels to record an image. For example, when a cameraman or camerawoman presses his or her camera's shutter button and exposure begins, each photodetector in the array is uncovered to detect the presence or absence of photons at the individual array locations. To end the exposure, the camera closes its shutter, and circuitry in the camera assesses how much light (e.g., how many photons) fell into each photodetector while the shutter was open. The relative quantity or intensity of photons that struck each photodetector are then stored according to a bit depth (0-255 for an 8-bit pixel). The digital values for all the pixels are then stored and are used to form a resultant image.

Conventional solid state image sensors are made up of an array of photodetectors which individually include PN junctions made of semiconductor material, for example, silicon disposed in a semiconductor substrate. Color filter arrays (CFAs) with separate color filters for red, blue, and green light are often arranged over photodetector arrays to differentiate between different colors of light. When an incident light ray has a large angle of incidence, the light can easily pass through one color filter into other neighboring color filters and/or other neighboring photodetectors underneath the color filters. Thus, a shield or re-direct element is inserted between photodetectors of different colors to reduce the crosstalk between photodetectors of different color filters, which otherwise will ultimately cause noise that distorts the resultant digital images.

BRIEF DESCRIPTION OF THE DRAWINGS

Aspects of the present disclosure are best understood from the following detailed description when read with the accompanying figures. It is noted that, in accordance with the standard practice in the industry, various features are not drawn to scale. In fact, the dimensions of the various features may be arbitrarily increased or reduced for clarity of discussion.

FIG. **1**A illustrates a cross-sectional view of some embodiments of an organic image sensor.

FIG. **1**B illustrates a cross-sectional view of some other embodiments of an organic image sensor.

FIG. **2** illustrates a cross-sectional view of some other embodiments of an organic image sensor.

FIG. **3** illustrates a top view of some embodiments of an organic image sensor.

FIG. **4** illustrates a flow diagram of some embodiments of a method of forming an organic image sensor.

FIGS. **5**A-F illustrate some embodiments of cross-sectional views of a method of forming an organic image sensor.

DETAILED DESCRIPTION

The following disclosure provides many different embodiments, or examples, for implementing different features of the provided subject matter. Specific examples of components and arrangements are described below to simplify the present disclosure. These are, of course, merely examples and are not intended to be limiting. For example, the formation of a first feature over or on a second feature in the description that follows may include embodiments in which the first and second features are formed in direct contact, and may also include embodiments in which additional features may be formed between the first and second features, such that the first and second features may not be in direct contact. In addition, the present disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed.

Further, spatially relative terms, such as "beneath," "below," "lower," "above," "upper" and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. The spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. The apparatus may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein may likewise be interpreted accordingly.

One type of solid state image sensor is an organic CMOS image sensor (CIS) that includes an organic photoelectrical conversion structure arranged between upper and lower electrodes. When incident radiation of sufficient energy strikes the organic photoelectrical conversion structure, an electron-hole pair is created. Due to a bias applied across the electrodes, the hole is accelerated toward one of the electrodes (e.g., towards the lower electrode acting as an anode), while the electron is accelerated toward the other electrode (e.g., towards the upper electrode acting as a cathode). In this way, the incident radiation produces a photocurrent between the electrodes, wherein the current level of this photocurrent is proportional to the intensity of the incident radiation absorbed.

To help decrease leakage, some organic CISs include electron-blocking and/or hole-blocking layers between the organic photoelectrical conversion structure and the various electrodes. For example, a hole-blocking layer can be inserted between the organic photoelectrical conversion structure and the cathode (e.g., upper electrode) to hinder holes moving from the cathode to the organic photoelectrical conversion structure. Similarly, an electron-blocking layer can be inserted between the organic photoelectrical conversion structure and the anode (e.g., lower electrode) to hinder electrons moving from the anode to the organic photoelectrical conversion structure. Thus, these electron/hole blocking layers can help to decrease leakage and improve efficiency of the cell. Unfortunately, in previous approaches, an electron- or hole-blocking layer is formed directly over an exposed surface of the organic photoelectrical conversion structure so the electron- or hole-blocking layer abuts the exposed surface of the organic photoelectrical conversion structure. In particular, this overlying electron- or hole-blocking layer is deposited by plasma vapor deposition (PVD), and this plasma process can damage the exposed surface of the organic photoelectrical conversion structure, thereby degrading the performance of the CIS.

Therefore, to ward off this potential PVD-damage, some embodiments of the present disclosure include one or more protection layers to help protect the surface of the organic photoelectrical conversion structure from plasma damage. In addition, in some embodiments, one or more protection layers are included to increase the electron- or hole-blocking capability of an electron- or hole-blocking layer between the organic photo active layer and the lower electrode.

Further, the organic photoelectric conversion structure may comprise organic conjugated materials that are easily degraded by reacting with oxygen and moisture. By covering the organic photoelectric conversion structure by these protection layers, reliability of the organic image sensor is improved. Thus, these protection layer(s) can help improve the overall performance, reliability, and/or efficiency of the CIS.

FIG. **1***a* shows a cross-sectional view of some embodiments of an organic image sensor **100**, which includes first and second protection structures **108**, **118** that are described in more detail below. The organic image sensor **100** includes an organic photoelectrical conversion structure **120** arranged between a first (lower) electrode **104**, and a second (upper) electrode **114**. The second electrode **114** is transparent in a predetermined wavelength range so photons **130** having wavelengths falling within a predetermined wavelength range pass through the second electrode **114** to strike to the organic photoelectrical conversion structure **120**. For example, the second electrode **114** can be made of a transparent conductive metal oxide such as ITO, FTO, AZO, IGZO, SnO2 and/or ZnO. When incident radiation of sufficient energy passes through the upper electrode **114** and is absorbed by the organic photoelectrical conversion structure **120**, an electron-hole pair is created. A voltage is applied across the first and second electrodes **104**, **114** so generated holes are accelerated toward one of the electrodes (e.g., towards the lower electrode **104** acting as an anode), while electrons are accelerated toward the other electrode (e.g., towards the upper electrode acting as a cathode). In this way, the incident radiation produces a photocurrent between the electrodes **104**, **114**, wherein the current level of this photocurrent is proportional to the intensity of the incident radiation absorbed.

First and second charge-blocking layers **106**, **116**, which block opposite types of charge, separate the organic photoelectrical conversion structure **120** from the first and second electrodes **104**, **114**, respectively. The second charge blocking structure **116** is transparent in the predetermined wavelength range to allow photons having wavelengths falling within the predetermined wavelength range to strike to the organic photoelectrical conversion structure **120**. For example, in embodiments where the first electrode **104** acts as an anode, the first charge-blocking layer **106** is an electron-blocking layer. Similarly, in embodiments where the second electrode **114** acts as a cathode, the second charge-blocking layer **116** is a hole-blocking layer. It will be appreciated that the anode and cathode could be flipped in other embodiments, such that the lower electrode **104** can alternatively act as a cathode while the upper electrode **114** can act as an anode, provided applied biases and polarities of the charge-blocking layers are also flipped.

Whatever the precise arrangement, the electron blocking structure (e.g. **106**) comprises material having a higher "lowest unoccupied molecular orbital" (LUMO)/conduction band (CB) energy than a work function of the anode. The electron blocking structure **106** can work as a hole transporting structure as well and the electron blocking structure (e.g., **106**) may correspondingly have an electro affinity smaller than a work function of the material of the anode (e.g., first electrode **104**) and an ionization potential smaller than the ionization potential of the adjacent organic photoelectrical conversion structure **120**. For example, the electron blocking structure may comprise an inorganic material, such as MoO_3, NiO, WO_3, CuO or V_2O_5, for example. Similarly, the hole blocking structure (e.g. **116**) comprises material having a lower highest occupied molecular orbital (HOMO)/valence band (VB) energy than a work function of the cathode. The hole blocking structure **106** can work as an electron transporting structure as well and the hole blocking structure (e.g., **116**) may correspondingly have an ionization potential large than a work function of the cathode (e.g., second electrode **114**) and an electron affinity larger than the electron affinity of the adjacent organic photoelectrical conversion structure **120**. For example, the hole blocking structure may comprise an inorganic material, such as LiF, TiO_2, ZnO, Ta_2O_5 or ZrO_2, for example.

A first protective structure **118** is disposed over the organic photoelectrical conversion structure **120**. The first protective structure **118** is disposed between the second charge blocking structure **116** and the organic photoelectrical conversion structure **120** and covers a top surface and a sidewall of the organic photoelectrical conversion structure **120**. The first protective structure **118** can be formed by ALD. In some embodiments, the first protective structure comprises aluminum oxide (Al_2O_3), aluminum nitride (AlN), or silicon oxide (SiO_2). The first protective structure **118** has a thickness in a range of from about 5 Å to about nm. 5 nm

In some embodiments, the image sensor **100** further comprises a second protective structure **108** disposed between the first electrode **104** and the first charge blocking structure **106**. The second protective structure **108** can comprise the same material as or a different material than the first protective structure **118**. The second protective structure can enhance electron/hole blocking of the first charge blocking layer **106**.

In some embodiments, the organic photoelectric conversion structure **120** is made up of an upper organic charge blocking layer **120***a*, a lower organic charge blocking layer **120***b*, and an organic photo active layer **120***c*. The organic photo active layer **120***c* may comprise one or more semiconducting, conjugated polymers, alone or in combination with non-conjugated materials. For example, the organic photo active layer **120***c* may comprise fullerene derivative (e.g. PTB7 and PC71BM). The organic photo active layer **120***c* may comprise a blend of two or more conjugated polymers or organic molecules with similar or different electron affinities and electronic energy gaps. The organic photo active layer **120***c* may also comprise a series of hetero-junctions utilizing layers of organic materials or the blends. The upper and/or lower organic charge blocking layers **120***a*, **120***b* can manifest as an electron blocking layer (or somewhat analogously as a hole transport layer) made up of Poly(3-hexylthiophene-2,5-diyl) (P3HT), Poly(3,4-ethylenedioxythiophene) Polystyrene sulfonate (PEDOT:PSS) or Poly[2-methoxy-5-(3',7'-dimethyloctyloxy)-1,4-phenylenevinylene] (MDMO-PPV). The upper and/or lower organic charge blocking layers **120***a*, **120***b* can also manifest as a hole-blocking layer (or somewhat analogously as an electron transport layer) made up of fullerene derivative and one or more than one n-type conjugated polymer. For example, the organic hole-blocking/electron transport layer can comprise 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (BCP), 2,2'-(1,3-Phenylene)bis[5-(4-tert-butylphenyl)-1,3,4-oxadiazole] (OXD-7), Tert-butyl Peroxyisobutyrate (TBPi) or 3-(Biphenyl-4-yl)-5-(4-tert-butylphenyl)-4-phenyl-4H-1,2,4-triazole (TAZ).

As shown in FIG. **1**B, in some other embodiments, the second protective structure **108'** can be disposed between the first charge blocking structure **106'** and the organic photoelectrical conversion structure **120**.

In some embodiments, some of the inorganic blocking structures **106**, **116** are formed by physical vapor deposition (PVD) which may introduce plasma damage to the organic photoelectric conversion structure if formed directly onto the organic photoelectric conversion structure. In some embodiments, by forming the protective structure **118** and/or **108** through chemical vapor deposition (CVD) method, in particular atomic layer deposition (ALD), the organic photo electric conversion structure **120** is protected from plasma damage as well as from moisture and other environmental contaminants.

FIG. **2** shows another example of an organic image sensor **200** in accordance with some embodiments. The organic image sensor **200** is made up of a plurality of individual optical sensors **242** (which can also be referred to as "pixels"). For convenience, FIG. **2** illustrates three pixels **234**, **236** and **238**, which will be described below as a red pixel **234**, a green pixel **236**, and a blue pixel **238**. It will be appreciated that although FIG. **2** illustrates three pixels **234-238**, optical sensors in accordance with this disclosure can include any number of pixels, ranging from a single pixel to billions or even more pixels. Further, the pixels are often arranged to follow a predetermined pattern, such as in a Bayer filter for example, where green pixels are arranged to correspond to one half of a checkerboard pattern and where the red and blue collectively establish the other half of the checkerboard pattern. See e.g., FIG. **3**. Patterns other than that of a Bayer filter could also be used.

Each pixel **242** includes multiple layers which are stacked on top of one another, and which are formed by photolithography techniques and/or by spin-on coatings, for example. The structure of each pixel **242** is largely the same and repeated. The organic image sensor **200** comprises a first electrode structure **204** (which may also be referred to as a "pixel electrode array" in some embodiments), an organic photoelectric conversion structure **220** disposed over the first electrode array **204**, a first protective structure **218** disposed over the organic photoelectric conversion structure **220**, a second electrode structure **214** (which may also be referred to as an "upper transparent electrode" in some embodiments) disposed over the first protective structure **218**, and a color filter array **210** disposed over the second electrode structure **214**. The organic photoelectric conversion structure **220** is configured to convert one or more photons having wavelengths falling with a predetermined wavelength range into an electrical signal.

In some embodiments, the organic photoelectric conversion structure **220** comprises an organic photo active layer, a p type organic hole transport layer and a n type organic electron transport layer. The second electrode structure **214** is transparent in the predetermined range. In some embodiments, the first electrode structure **204** can comprise metal and the second electrode structure **214** can comprise at least one of: ITO, FIO, AZO, or IGZO. One or both of the first and the second electrode structures **204** and **214** are an electrode array having separate components for each pixel **242**. The first protective structure **218** is disposed between the organic photoelectric conversion structure **220** and the second electrode structure **214** and covers a top surface and a perimeter of the organic photoelectric conversion structure **220**. In some embodiments, the first protective layer **218** covers sidewalls of the organic photoelectric conversion structure **220** to protect the organic photoelectric conversion structure **220** from moisture and oxygen and/or from plasma damage. In some embodiments, the organic image sensor **200** further comprises some inorganic charge blocking structures to suppress the leakage in the dark. For example, an inorganic hole blocking structure **216** can be disposed between the first protective structure **218** and the second electrode structure **214** to prevent a hole from moving from the second electrode structure **214** to the organic photoelectrical conversion structure **220**. Although the pixels **242** are similar in many respects, the pixels differ from one another in that the corresponding color filter provides different wavelength specificity. Each color filter of the color filter array **210** passes light of a predetermined frequency range there through, while blocking light of other frequency ranges. For example, the red pixel **234** includes a red color filter **210***a*, which allows red light to pass there through while blocking other wavelengths of light (e.g., red color filter **210***a* blocks blue and green light). The green pixel **236** includes a green color filter **210***b* that allows green light there through while blocking other wavelengths of light (e.g., green color filter **210***b* blocks red and blue light). The blue pixel **238** includes a blue color filter **210***c* that allows blue light to pass there through while blocking other wavelengths of light (e.g., blue color filter **210***c* blocks red and green light).

During operation, polychromatic light approaches the optical sensor **200** as shown by arrow **230**, and strikes the upper surfaces of the color filters **210** at a substantially normal angle of incidence, for example. The polychromatic light **230** is filtered to contain only a narrow spectrum of light as it passes through each color filter **210**. This filtered light then passes through the upper transparent electrodes **214** and through transparent charge-blocking structure **216** and strikes the photoelectric conversion layers **220**. In the photoelectric conversion layer **220**, the light is converted from a photon or electromagnetic wave into an electrical signal, such as a voltage or current. The voltage level or current level, which is established between the first and second electrodes **204**, **214**, corresponds to the intensity of light that strikes the photoelectric conversion layer **220** for a given pixel. This electrical signal is then passed down through interconnect structures **222** to read out circuitry **224** formed in a substrate **226**. In some embodiments, the read out circuitry **224** can be a CMOS circuitry. The substrate **226** can be a semiconductor substrate, a plastic substrate or any other suitable substrates. The read out circuitry **224** then uses an algorithm, such as a demosaicing algorithm, to generate a digital image from the electrical signals provided by the array of pixels.

FIG. **4** shows a flow diagram of some embodiments of a method **400** of forming an organic image sensor. While disclosed methods (e.g., methods **400**) are illustrated and described below as a series of acts or events, it will be appreciated that the illustrated ordering of such acts or events are not to be interpreted in a limiting sense. For example, some acts may occur in different orders and/or concurrently with other acts or events apart from those illustrated and/or described herein. In addition, not all illustrated acts may be required to implement one or more aspects or embodiments of the description herein. Further, one or more of the acts depicted herein may be carried out in one or more separate acts and/or phases.

At **402**, a first electrode layer is formed over a substrate.

At **404**, an electron blocking layer is formed over the first electrode layer.

At **406**, an organic photoelectrical conversion layer is formed over the electron blocking layer.

At **408**, a portion of the organic photoelectrical conversion layer is removed to form a recess that circumscribes at a perimeter of an organic photoelectrical conversion structure.

At **410**, a conformal protective structure is formed over the organic photoelectrical conversion structure covering a top surface and filling the removal perimeter portion of the organic photoelectrical conversion structure covering a sidewall of the organic photoelectrical conversion structure.

At **412**, a hole blocking layer is formed over the conformal protective structure. In some embodiments, the hole-blocking layer is formed by PVD, and the protection layer formed in **410** protects the organic photoelectrical conversion structure from this PVD process.

At **414**, a second electrode layer is formed over the hole blocking layer.

FIGS. **5***a*-**5***h* show some embodiments of cross-sectional views of protection barrier structure showing a method of forming protection barrier for an integrated microsystem.

Although FIGS. **5***a*-**5***h* are described in relation to method **400**, it will be appreciated that the structures disclosed in FIGS. **5***a*-**5***h* are not limited to such a method.

As shown in FIG. **5***a*, a first electrode layer **504** is formed over a substrate **502**. For example, the substrate **502** can be a semiconductor substrate, for example, silicon, or a plastic substrate and the first electrode layer **504** can be made of metal, such as silver, gold, aluminum, titanium, copper, platinum, palladium, and/or nickel. The first electrode can also be made of metal nanowire, a carbon nanotubes or a conductive polymer. A surface treatment can be performed and an adhesion assisting layer can be prepared to the substrate **502** to improve the adhesion property of a coating solution. In some embodiments, the substrate **502** is transparent at a predetermined wavelength range, such that light strikes the sensor through the bottom face of the substrate **502***a*. For example, the substrate **502** can be made of glass or resin. In this alternative case, the first electrode layer **504** can be made of a transparent conductive metal oxide such as ITO, FTO, AZO, IGZO, SnO2 and/or ZnO. A transparent substrate, if present, is not particularly limited and known materials having any shape, structure, thickness and the like can be used. The first electrode **504** has a thickness in a range of from about 50 nm to about 200 nm.

As shown in FIG. **5***b*, an electron blocking layer **506** is formed over the first electrode layer **504**. In some embodiments, a second protective layer **508** can be formed between the first electrode layer **504** and the electron blocking layer **506**. The electron blocking layer **506** can comprise PEDOT:PSS, high K (MoO_3, NiO, CuO, WO_3, V_2O_5). The electron blocking layer **506** can have a thickness in a range of from about 5 nm to about 20 nm. The second protective layer **508** can have a bandgap larger than 3 eV. The second protective layer **508** can comprise Al_2O_3, MN, or SiO_2. The second protective layer **508** can have a thickness in a range of from about 0.5 nm to about 10 nm.

As shown in FIG. **5***c*, an organic photoelectrical conversion layer **520** is formed over the electron blocking layer **506**. In general, the organic photoelectric conversion layer **502** comprises a p-type layer and an n-type layer. In some embodiments, the p-type layer directly abuts the n-type layer to form a p-n junction, but in other embodiments an intrinsic layer is arranged between the p- and n-type layers to form a PIN junction. The p-type layer helps hole transport and can comprise P3HT, MDMO-PPV or other applicable material having a thickness in a range of from about 5 nm to about 20 nm. The n-type layer helps electron transport and can comprise fullerene derivative and one or more conjugated polymers having a thickness in a range of from about 5 nm to about 20 nm. The organic photoelectrical conversion layer **520** can further comprise an active layer comprising conjugated polymers and fullerene derivatives (e.g. PTB7 and PC71BM). The organic photoelectrical conversion layer **520** can have a thickness in a range of from about 100 nm to about 500 nm.

As shown in FIG. **5***d*, a portion of the organic photoelectrical conversion layer **520** is removed to form a recess **550** that circumscribes at a perimeter of an organic photoelectrical conversion structure **520'**.

As shown in FIG. **5***e*, a conformal protective structure **518** is formed over the organic photoelectrical conversion structure **520'** covering a top surface and filling the removal perimeter portion **550** of the organic photoelectrical conversion structure **520'** covering a sidewall of the organic photoelectrical conversion structure **520'**. The conformal protective structure **518** is formed by ALD at a relative low temperature. The conformal protective structure **518** can have a bandgap larger than 3 eV. The conformal protective structure **518** can comprise Al_2O_3, MN, or SiO_2. The conformal protective structure **518** can have a thickness in a range of from about 0.5 nm to about 10 nm. The conformal protective structure **518** can be made of same or different material with the second protective structure **508**.

As shown in FIG. **5***f*, a hole blocking structure **516** is formed over the conformal protective structure **518**. A second electrode structure **514** is formed over the hole blocking layer **516**. The hole blocking layer **516** can comprise LiF, TiO_2, ZnO, Ta_2O_5 or ZrO_2. The hole blocking layer **516** can have a thickness in a range of from about 5 nm to about 20 nm. The second electrode structure **514** can be made of a transparent conductive metal oxide, metal bulk, metal nanowire, a carbon nanotubes or a conductive polymer. Notably, The first and second electrode structures **504** and **514** work as a cathode and an anode can be switchable along with the electron blocking structure **506'** and the hole blocking structure **516**, according to the device structure. The thin film protective structures **508** and **518** fabricated by CVD can be disposed covering surfaces of the organic photoelectrical conversion structure **520'** to help suppress the dark current and decrease damage introduced by the following processes.

In some embodiments, the present disclosure relates to an organic image sensor. The organic image sensor comprises a first electrode, an organic photoelectrical conversion structure disposed over the first electrode and a second electrode disposed over the organic photoelectrical conversion structure. The organic photoelectrical conversion structure is configured to convert one or more photons having wavelength falling within a predetermined wavelength range into an electrical signal. The second electrode is transparent in the predetermined wavelength range. The organic image sensor further comprises a first charge blocking structure disposed between the first electrode and the organic photoelectrical conversion structure to restrain a first kind of electric charge to move from the first electrode to the organic photoelectrical conversion structure and a second charge blocking layer disposed between the organic photoelectrical conversion structure and the second electrode to restrain a second kind of electric charge to move from the second electrode to the organic photoelectrical conversion structure. The organic image sensor further comprises a first protective structure disposed between the second charge blocking layer and the organic photoelectrical conversion structure covering a top surface and a sidewall of the organic photoelectrical conversion structure.

In other embodiments, the present disclosure relates to an organic image sensor. The organic image sensor comprises a pixel electrode array disposed over a substrate, an organic photoelectrical conversion structure arranged over the first electrode array, a transparent electrode structure disposed over the organic photoelectrical conversion structure, a color filter array disposed over the transparent electrode structure, and a first protective structure disposed between the transparent electrode structure and the organic photoelectrical conversion structure. The organic photoelectrical conversion structure is configured to convert one or more photons having wavelength falling within a predetermined wavelength range into an electrical signal. The transparent electrode structure is transparent in the predetermined wavelength range. Respective color filters are aligned to respective pixel electrodes of the pixel electrode array. The first protective structure extends to cover a perimeter of the organic photoelectrical conversion structure.

In yet other embodiments, the present disclosure relates to a method of forming an organic image sensor. In the method, a first electrode layer is formed over a substrate. Then, an electron blocking layer is formed over the first electrode layer. Then an organic photoelectrical conversion layer is formed over the electron blocking layer. Then a portion of the organic photoelectrical conversion layer is removed to form a recess that circumscribes at a perimeter of an organic photoelectrical conversion structure. Then a conformal protective structure is formed over the organic photoelectrical conversion structure covering a top surface and filling the removal perimeter portion of the organic photoelectrical conversion structure covering a sidewall of the organic photoelectrical conversion structure. At last, a hole blocking layer is formed over the conformal protective structure.

The foregoing outlines features of several embodiments so that those skilled in the art may better understand the aspects of the present disclosure. Those skilled in the art should appreciate that they may readily use the present disclosure as a basis for designing or modifying other processes and structures for carrying out the same purposes and/or achieving the same advantages of the embodiments introduced herein. Those skilled in the art should also realize that such equivalent constructions do not depart from the spirit and scope of the present disclosure, and that they may make various changes, substitutions, and alterations herein without departing from the spirit and scope of the present disclosure.

What is claimed is:

1. An organic image sensor, comprising:

a first electrode;

an organic photoelectrical conversion structure disposed over the first electrode to convert one or more photons having wavelength falling within a predetermined wavelength range into an electrical signal;

a second electrode disposed over the organic photoelectrical conversion structure, wherein the second electrode is transparent in the predetermined wavelength range; and

a first charge blocking structure disposed between the first electrode and the organic photoelectrical conversion structure to restrain a first kind of electric charge to move from the first electrode to the organic photoelectrical conversion structure;

a second charge blocking structure disposed between the organic photoelectrical conversion structure and the second electrode to restrain a second kind of electric charge to move from the second electrode to the organic photoelectrical conversion structure; and

a first protective structure disposed between the second charge blocking structure and the organic photoelectrical conversion structure covering a top surface and a sidewall of the organic photoelectrical conversion structure.

2. The organic image sensor of claim **1**, wherein the first protective structure is formed by atomic layer deposition (ALD).

3. The organic image sensor of claim **1**, wherein the second charge blocking structure is a hole blocking layer comprising LiF, TiO_2, ZnO, Ta_2O_5 or ZrO_2.

4. The organic image sensor of claim **1**, wherein the first charge blocking structure is an electron blocking layer comprising MoO_3, NiO, WO_3, CuO or V_2O_5.

5. The organic image sensor of claim **1**, further comprising:

a second protective structure disposed between the first electrode and the first charge blocking structure.

6. The organic image sensor of claim **5**, wherein the second protective structure is made up of a same material with the first protective structure.

7. The organic image sensor of claim **1**, wherein the first protective structure has a thickness in a range of from about 5 Å to about 5 nm.

8. The organic image sensor of claim **1**, wherein the first protective structure comprises aluminum oxide (Al_2O_3), aluminum nitride (AlN), or silicon oxide (SiO_2).

9. An organic image sensor, comprising:

a first pixel electrode array disposed over a substrate;

an organic photoelectrical conversion structure arranged over the first electrode array to convert one or more photons having wavelength falling within a predetermined wavelength range into an electrical signal;

a transparent electrode structure disposed over the organic photoelectrical conversion structure, wherein the transparent electrode structure is transparent in the predetermined wavelength range;

a color filter array disposed over the transparent electrode structure, wherein respective color filters are aligned to respective pixel electrodes of the pixel electrode array; and

a first protective structure disposed between the transparent electrode structure and the organic photoelectrical conversion structure extending to cover a perimeter of the organic photoelectrical conversion structure.

10. The organic image sensor of claim **9**, wherein the first protective structure keeps the organic photoelectrical conversion structure from moisture and oxygen.

11. The organic image sensor of claim **9**, wherein the organic photoelectrical conversion structure comprises an organic photo active layer, an organic hole transport layer and an organic electron transport layer.

12. The organic image sensor of claim **9**, wherein the first protective structure covers a top surface and sidewall of the organic photoelectrical conversion structure.

13. The organic image sensor of claim **9**, further comprising:

an inorganic electron blocking structure disposed between the pixel electrode array and the organic photoelectrical conversion structure to restrain an electron to move from the pixel electrode array to the organic photoelectrical conversion structure; or

an inorganic hole blocking structure disposed between the first protective structure and the transparent electrode structure to restrain a hole to move from the transparent electrode structure to the organic photoelectrical conversion structure.

14. The organic image sensor of claim **13**, further comprising:

a second protective structure disposed between the pixel electrode array and the electron blocking structure, wherein the second protective structure is made of a same or different material as the first protective structure.

15. The organic image sensor of claim **14**, wherein the second protective structure increases a blocking capability of the electron blocking structure.

16. The organic image sensor of claim **9**, further comprising:

a CMOS read out circuitry in the substrate under the pixel electrode array.

17. The organic image sensor of claim **9**, wherein the pixel electrode comprises metal and the transparent electrode comprises at least one of: ITO, FIO, AZO, or IGZO.

18. The organic image sensor of claim **9**, wherein the substrate can be a semiconductor or plastic substrate.

19. A method of forming an organic image sensor comprising:

forming a first electrode layer over a substrate;

forming an electron blocking layer over the first electrode layer;

forming an organic photoelectrical conversion layer over the electron blocking layer;

removing a portion of the organic photoelectrical conversion layer to form a recess that circumscribes at a perimeter of an organic photoelectrical conversion structure;

forming a conformal protective structure over the organic photoelectrical conversion structure covering a top surface and filling the removal portion of the organic photoelectrical conversion structure covering a sidewall of the organic photoelectrical conversion structure;

forming a hole blocking layer over the conformal protective structure; and

forming a second electrode layer over the hole blocking layer.

20. The method of claim **19**, wherein the electron blocking layer is formed by physical vapor deposition (PVD) and the protective structure is formed by atomic layer deposition (ALD).

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